Quantitative Literacy in a Reform-based Curriculum and Implications for Assessment

Jane Skalicky

University of Tasmania

Abstract

This position paper considers the need for a new perspective on assessment in examining the place of quantitative literacy in a reform-based curriculum. Quantitative literacy, an ability to apply quantitative ideas in new or unfamiliar contexts, is essential for any individual who wishes to participate fully in democratic society. Alongside growing awareness of the importance of this quantitative reasoning capability is a curriculum reform movement that emphasises values-based, authentic experiences over discipline-based learning. In Tasmania, this curriculum reform is centred on five Essential Learnings: thinking, communicating, personal futures, world futures and social responsibility. The very nature of quantitative literacy necessitates its assessment in connection with its context, in this case, the key elements of the Essential Learnings. Examination of existing assessment practices points to the need for an assessment model that enables concurrent assessment of two major elements: the quantitative skills and concepts being applied *and* the contextual elements within which they are being applied. This is demonstrated with two examples of external assessment items and two examples of classroom-based units of work. This paper discusses the issues whose resolution will contribute to the development of a new model of assessment of quantitative literacy in the new reform-based environment.

Introduction

Two innovative developments are occurring in education today: growing awareness of quantitative literacy and reform to school curricula. This study considers the relationship between the two and the resulting implications for assessment. After providing background for these two developing areas, a specific framework is set using the reform currently taking place in Tasmania. Given the goal to meet standards across the new curriculum, the implications for assessment are considered. Four examples that demonstrate existing quantitative literacy assessment practices are reviewed and the implications for further research are explored.

Background – Quantitative Literacy

This section describes the growing interest in quantitative literacy and how this field is being defined across the globe. The definitions included are only a few among many that are currently used to grapple with the issue of quantitative literacy in today's information society. The concepts and skills required to meet the quantitative demands of everyday life are defined and examined under various names including quantitative literacy, mathematical literacy, and numeracy.

Discussion amongst academics, mathematicians, and industry leaders, concerning quantitative literacy, revolves around its increasing relevance for today's citizens. This conversation has extended to those involved in education at the school level and

explores how to bring about learning that acknowledges the quantitative challenges of life in the twenty-first century.

> Quantitative literacy is more than a skill set; it is a crucial part of understanding and comprehension, an approach to reading, writing, and analysing information. Students should be learning to think critically and constructively as they read the daily newspaper, compare election candidates, respond to surveys, participate in a public protest, balance their budgets, or even eventually join the dot-com world. (Sharpe, 2002, p.C3)

The term 'quantitative literacy' was used as early as 1974 when Professor Jerrold Zacharias of Massachusetts Institute of Technology identified "the varieties of competence that a citizen must possess in order to handle the matters and arguments that affect him and his country and his world" (p. 9). The elements identified by Zacharias as being required for general quantitative competence included arithmetic, number lines, simple measurements, graphs and maps, rates of change, and statistical distributions. Public discourse surrounding quantitative literacy has grown significantly since this time, principally as a result of the writings and edited works of Lynn Arthur Steen, professor of mathematics at St. Olaf College in Minnesota, as documented in the publications, *Why Numbers Count* (Steen, 1997), *Mathematics and Democracy* (Steen, 2001) and *Quantitative Literacy: Why Numeracy Matters for Schools and Colleges* (Madison & Steen, 2003). A comprehensive definition of quantitative literacy is detailed in Steen's case statement (2001), where he describes ten elements of quantitative literacy: confidence with mathematics, cultural appreciation, interpreting data, logical thinking, making decisions, mathematics in context, number sense, practical skills, prerequisite knowledge, and symbol sense.

The Organisation for Economic Cooperation and Development (OECD) Programme for International Student Assessment (PISA), a three-yearly survey of the knowledge and skills of 15-year-olds in the principal industrialised countries, defines mathematical literacy as:

> An individual's capacity to identify and understand the role that mathematics plays in the world, to make well-founded mathematical judgements and to engage in mathematics, in ways that meet the needs of that individual's current and future life as a constructive, concerned and reflective citizen. (PISA, 2000)

In Australia, the term numeracy is used to describe the quantitative capabilities of both students and adults. A view, beyond the ability to handle number concepts in context, is reflected by the Australian Association of Mathematics Teachers (AAMT) definition:

> To be numerate is to use mathematics effectively to meet the general demands of life at home, in paid work, and for participation in community and civic life.
> In school education, numeracy is a fundamental component of learning, discourse and critique across all areas of the curriculum. It involves the disposition to use, in context, a combination of:
>
> - Underpinning mathematical concepts and skills from across the discipline (numerical, spatial, graphical, statistical and algebraic);
> - Mathematical thinking and strategies;
> - General thinking skills; and
> - Grounded appreciation of context. (AAMT, 1998)

The terms quantitative literacy and numeracy are used interchangeably in this paper and reflect a comprehensive view as defined by Steen (2001).

Quantitative thinking has become an essential disposition for any individual who wishes to participate fully in a democratic society, to apply not only knowledge and skills, but also critical reasoning capabilities, to everyday life. Citizens are making judgments and decisions on a daily basis with regard to the situations they encounter, be they personal, work-related, or on a broader societal level. “In the twenty-first century, literacy and numeracy will become inseparable qualities of an educated person” (Steen, 2001, p. 9). There are endless examples in daily life and in the media where an ability to analyse information critically is required to make informed judgments. Politicians, media, and industry are talking regularly about many issues that impact people’s lives, such as interest rates, medicare policy, and national security. At an individual level people are dealing daily with work-related challenges and issues such as personal finance, health, shopping choices, and time management.

The foundation of quantitative literacy is the ability to apply quantitative ideas in new or unfamiliar contexts. Quantitative literacy is not a watering-down of the mathematics curriculum, but rather a raising of the standard for all students with regard to the application of mathematical concepts in contexts that are relevant to them. Studies have demonstrated improved mathematics learning when skills and concepts are experienced in a real-world context that has meaning for the students (Bonotto & Basso, 2001; de Corte, Verschaffel, & Greer, 2000; Ronau & Karp, 2001; Steen, 1999). However, creating a culture for learning mathematics differently that allows for reflective thinking and reasoning poses challenges and teacher influence should not be underestimated. Teachers require the knowledge, understandings, and connections themselves in order to facilitate effective student learning (Ma, 1999). These are some of the issues that need to be considered in the context of the current reform movement regarding school curricula

Curriculum Reform and Quantitative Literacy

What competencies do adults need in order to live successfully in this century? This is the question that drives educators to examine school curricula and address these needs with regard to the students of today. Current curriculum reforms are based upon the perception that adults today require multiple literacies in order for them to lead interesting, responsible and productive lives. They focus on a coherent set of the most important ideas and skills for students – sometimes referred to as ‘‘big ideas’’. The aim is for conceptual understanding rather than procedural understanding (Blythe, 1998; Rafferty, 1999; Scott, 2001). Some Australian states are currently reconceptualising curriculum in terms of these big ideas that enable students to become productive and critical members of society. The curricula are values-based, rather than discipline-based, with an emphasis on authentic learning experiences. Three Australian states, namely, Queensland, South Australia, and Tasmania, are committed to the reform that finds its foundations in distributed cognition, the belief that knowledge is socially constructed as a result of the interaction between teaching and learning (Lave, 1988).

Juxtaposed with this curriculum reform at the state level is the concern at Commonwealth level for the need for high level quantitative, scientific, and technological literacy and for innovation to occur if Australia is to continue to grow as a knowledge-based economy and society.

> Special emphasis is needed now on improving scientific and mathematical education and technological capability. (Committee for the Review of Teaching and Teacher Education, 2003b)

> A fundamental question being asked as part of this process is how schools can best develop, in all students, a capacity to innovate, to be creative and to take great control of their lives… (Committee for the Review of Teaching and Teacher Education, 2003a)

There is certainly much debate amongst educators about the place of the disciplines in the new reform curricula frameworks. An authentic curriculum aimed at engendering understanding through engagement will improve the general level of multiple literacies for future generations. Likewise, people with singularly well-developed expertise are necessary to push the boundaries of innovation in our society. These two facts do not have to be at odds. The needs for both numerate citizens, *and* innovative and creative scientists, mathematicians, and technologists, are not mutually exclusive. An educational framework that embeds quantitative literacy as one of the key cornerstones is also one focused on the development of lasting conceptual understandings. The test of this understanding, with regard to quantitative literacy, as for any other literacy, is whether a student is able to apply the appropriate skills in many different contexts. This transferability of knowledge and skills is a key aspect of quantitative literacy and necessitates it being the responsibility of the whole school community, not just the mathematics teacher.

Therein lies a monumental challenge. Before numeracy will be viewed as, and taught on an equal footing with, general literacy, cultural change is needed on both a societal and educational level. Students, parents, and the wider community need to be educated to enable the core cultural values and beliefs about mathematics to evolve and result in a change in the expectations for the teaching and learning of mathematics (Scott, 2001). Research has highlighted the complex nature of curriculum reform and the requirement for the coordination of all parts of the educational system to enable any likelihood of improved student learning. Case studies of two elementary schools undergoing reform in Washington in the United States identified six dimensions of school capacity: principal leadership; professional community; program coherence; technical resources; knowledge, skills, and dispositions of individual teachers; and learning opportunities for teachers (Borko, 2003).

Initial results being reported in the United States, following the implementation of a Standards-based reform mathematics curriculum (National Council of Teachers of Mathematics, 1989), point to an overall rise in the mathematics achievement of students in the Pittsburgh district (Briars, 1999). Tasks assessed incorporated skills, concepts, and problem solving, and achievement gains were high in all three areas over the three years of the study. Reform in mathematics education in the United States has been focused in the mathematics classroom, whereas this study investigates quantitative literacy in a setting of systemic curriculum reform.

Much comment has been made concerning the need for quantitative literacy to be the responsibility, not only of the mathematics teacher, but also of the other disciplines as well, if students are going to have the opportunity to see numeracy as relevant to all aspects of their learning (Berlin, 2003; Frykholm, 2002; Price, 1997).

> Only by making quantitative ideas as pervasive in the curriculum as they are in life will numeracy become, like literacy, part of the fabric of liberal education. (Steen, 2000, p. 30)

> Instructors in middle school, high school and college need to join forces to deepen students' understanding of basic mathematics and to provide opportunities for students to become comfortable analyzing quantitative arguments in context… The development of quantitative literacy is the responsibility of individuals throughout the education system. (Hughes-Hallett, 2003, p. 92)

In the setting of schooling in Tasmania the development of a reform-based curriculum was initiated in 2000 in response to the Tasmanian Learning Together initiative. This initiative was established with the aim of helping Tasmanians create a shared vision for the next 20 years and it recognised the need for a curriculum that addresses the knowledge, skills and confidence required of students in the context of the twenty-first century.

The Tasmanian curriculum is centred around five Essential Learnings which are structured as shown in Figure 1. This transdisciplinary framework provides a unique opportunity to examine the place of quantitative literacy and its association with the 18 key elements of the framework.

Thinking o Inquiry o Reflective Thinking
Communicating o Being literate o Being numerate o Being information literate o Being arts literate
Personal Futures o Building and maintaining identity and relationships o Maintaining health and well-being o Being ethical o Creating and pursuing goals
Social Responsibility o Building social capital o Valuing diversity o Acting democratically o Understanding the past and creating preferred futures
World Futures o Investigating the natural and constructed world o Understanding and evaluating technological solutions o Creating sustainable futures o Understanding systems

Figure 1. The Essential Learnings Framework
(adapted from Department of Education Tasmania (DoET), 2002a, p. 7)

In moving to this values-based curriculum a comprehensive view of numeracy as expounded by Steen (2001) and the need for numeracy to be taught in an integrated setting must be reflected. Therefore, numeracy not only belongs in the key element "being numerate", but also must be developed across all of the 'Essential Learning' key elements as listed above in Figure 1. In addition to being a vehicle for developing critical and reflective thinking, quantitative literacy has the ability to enhance students' understandings of their personal futures, world futures and social responsibilities.

The Department of Education, Tasmania reflects this view in its current definition of numeracy:

> Being numerate involves having those concepts and skills of mathematics that are required to meet the demands of everyday life. It includes having the capacity to select and use them appropriately in real settings.
>
> Being truly numerate requires the knowledge and disposition to think and act mathematically and the confidence and intuition to apply particular mathematical principles to everyday problems. An opportunity to understand and use pattern, order and classification through first-hand experiences builds vital conceptual foundations for thinking and representation beyond the concrete and the immediate. These understandings are fundamental to being numerate. Access to high levels of abstract symbolic operation opens new ways of thinking and future academic and vocational pathways.
>
> Being numerate not only includes numeracy skills and understandings, but it also involves the critical and life-related aspects of being able to interpret information thoughtfully and accurately when it is represented in numerical and graphical form. This aspect of numeracy is akin to critical literacy – being able to recognise that information can be constructed to influence the reader or viewer. Developing the critical skills to analyse quantitative and spatial information when it is presented in various forms – for example graphs, tables, spreadsheets, charts and comparative models – enables young people to make more informed decisions, personally in everyday life, as consumers and as citizens. (DoET, 2002a, p. 21)

It is clear from this definition that numeracy entails both thinking and communicating, it plays a role in all the other Essential Learning outcomes, and it is a basic concern for all schools and the community.

Implications for Assessment

Quantitative literacy is about understanding rather than proficiency and therefore for assessment to be authentic, it must reflect the context. "Quantitative literacy demands evidence of students' abilities to grapple with realistic or 'situated' problems" (Wiggins, 2003, p. 126). Wiggins identifies this realistic or authentic nature of tasks as requiring students to utilise knowledge and abilities as people would utilise them in the real world. He stipulates four elements of an authentic task: it asks the student to use knowledge and skills to solve an unstructured problem; it requires judgment and innovation; it reflects the contexts in which adults are tested in the workplace, civic life, and in personal life; and it allows appropriate opportunities for feedback and revision.

> An assessment task, problem, or project is realistic if it is faithful to how mathematics is actually practiced when real people are challenged by problems involving numeracy. The task(s) must reflect the ways in which a person's knowledge and abilities are tested in real-world situations. (Wiggins, 2003, p. 127)

The two elements of education that have the most significant influence on determining what is taught in classrooms are curriculum and assessment (Resnick & Resnick, 1985). It is therefore crucial that any major change in curriculum and pedagogy, as is occurring in the Tasmanian setting, must be matched with an appropriate change in assessment practices. For the Tasmanian curriculum to be a truly authentic, values-based curriculum the assessment of students learning must also be founded on authentic pedagogical practices.

Newmann and his colleagues (1996) defined authentic pedagogy as incorporating both authentic instruction and authentic assessment and found this authentic pedagogy to be a strong predictor of students producing high quality authentic work.

> The term authentic achievement thus stands for intellectual accomplishments that are worthwhile, significant, and meaningful, such as those undertaken by successful adults: scientists, musicians, business entrepreneurs, politicians, crafts people, attorneys, novelists, physicians, designers, and so on. … For students we define authentic academic achievement through three criteria critical to significant intellectual accomplishment: construction of knowledge, disciplined inquiry, and the value of achievement beyond school. (Wehlage, Newmann, & Secada, 1996, p. 64)

Authentic work not only is the application of knowledge and concepts in real-world contexts, but also demands the cognitive challenge of obtaining one's own knowledge and deep understanding of concepts and ideas by undertaking intellectual work within these real-world contexts. This view supports the examination of quantitative literacy within the Essential Learnings framework. The key elements – being literate, being numerate, being information literate, inquiry, and reflective thinking – contribute to an emerging definition of quantitative literacy and bring the essential intellectual work required for authentic pedagogy to become a reality in this reform-based curriculum. The Essential Learnings elements of Social Responsibility, Personal Futures, and World Futures provide the opportunity to develop students' quantitative thinking and understandings in authentic contexts that are planned and relevant rather than the adhoc use of context seen in most mathematics classrooms.

> When our schools practice educative assessment, our children and our teachers come to see assessment as central to learning, as linked to real-world demands (and hence to incentives), and as worthy of attention. (Wiggins, 1998)

The conceptualisation of assessment has shifted considerably in the last ten years and much has been published concerning assessment that is educative, is an integrated part of teaching and learning, and is aimed to improve student performance (Blythe, 1998; Newmann, 1996; Wiggins, 1998; Wiske, 1998). Despite this shift, the move towards new forms of assessment, in particular performance-based assessment of student levels of understanding, is inconsistent (Dwyer, 1998). Support for reform and performance assessment at classroom level is occurring at the same time as an increasing use of standardized and external testing.

Assessment items examining mathematical literacy, numeracy, or quantitative literacy have moved towards a reflection of the importance of authenticity by embedding key mathematical skills to be tested in a context or story that provides relevance to the skills to be tested. Despite this move items tend to reduce this context to a minimum and even the richest of items do not ask the student to reflect on the contextual information further than to find the mathematics within the problem presented.

Wilkins (2000) examined the Third International Mathematics and Science Study (TIMMS) from the perspective of five components of quantitative literacy: mathematical content knowledge, mathematical reasoning capability, recognition of societal impact and utility of mathematics, understanding of nature and historical development of mathematics, and disposition towards mathematics. Although Wilkins acknowledged the rich data source that the TIMMS study offered he casts a timely warning:

> future research needs to focus on creating measures that more precisely capture the essence of each component of quantitative literacy… In addition, the effects of different curricula and instructional methods on the development of quantitative literacy should be examined. (Wilkins, 2000, p. 416)

Similarly, the United States National Research Council (NRC) Mathematics Learning Study argues that a mature conception of "mathematical literacy in the digital era" (Kilpatrick, 2001) is required and that any revolution in the teaching of mathematics must be grounded in research.

In examining the relationship between quantitative literacy and the key elements of the Essential Learnings, the implementation of an authentic pedagogy implies much more than the separate assessment of students' understandings of traditionally different disciplines. The very nature of quantitative literacy as discussed in this paper requires its assessment in connection with its context. It is necessary to explore the potential for performance items to concurrently assess multiple aspects of understanding.

In the context of the Essential Learnings Framework being implemented in Tasmanian schools, the key elements such as maintaining well-being, valuing diversity, acting democratically, creating sustainable futures, and investigating the natural and constructed world, provide the rich contexts in which to embed quantitative literacy. The authentic assessment of both quantitative literacy and the situated key elements is enabled by developments in assessment and measurement practice that acknowledges the complex nature of understanding. Wiggins and McTighe (1998) developed a six-faceted view of how understanding in context manifests itself. The six facets of understanding are: can explain, can interpret, can apply, have perspective, can empathize, and show self-knowledge. Understanding is inseparable from its context and the implication for assessment in the reform curriculum setting being examined is crucial. Context must not be reduced to a minimum in performance-based assessments of understanding for the purpose of identifying key skills to be measured. The significant correlation between authentic instruction and authentic assessment (Avery, 1999) necessitates that educational systems do not settle for the easy path of examining quantitative literacy in contexts without making the most of those contexts themselves.

Assessment in Practice

An examination of existing forms of assessment from a quantitative literacy perspective that incorporates the principles underlying reform-based curricula reveals two extremes of focus: first, external assessment items such as those conducted by PISA and TIMMS and, second, classroom-based units of work that are designed to integrate mathematics into real-world contexts. Two examples of each of these extremes are discussed to reveal the shortfalls of these approaches in meeting the view that has been developed in this paper.

External Assessment Items

Example 1 – Heartbeat

The focus of the PISA 2003 Assessment Framework (OECD, 2003) was on mathematical literacy as defined earlier. A sample task, entitled "*Heartbeat*" (p. 64) provides background information on the health issue of heart rate and physical effort. It provides two formulae for determining the recommended maximum heart rate (HR), dependent on the age of a person – the traditional formula (HR = 220 – age) and one based upon more recent research (HR = 208 – (0.7 x age)). The assessment items ask the student first, to calculate from which age onwards the recommended maximum heart rate increases as a result of using the new formula and second, to write down a formula for calculating the heart rate for the most effective physical training, based upon research that demonstrated that training is most effective when the heartbeat is at 80% of the recommended maximum heart rate.

Despite the rich contextual information that surrounded the mathematical problem, the aim of the item was to have the student determine the mathematics to be employed, and the context provided was ultimately irrelevant. This item reflects the vast majority of attempts to assess quantitative literacy. Placed in the framework of the Tasmanian Essential Learnings, Figure 1, the item could be adapted within the key element, maintaining health and well-being. There is much intellectual work that could be developed surrounding the health issues concerned with physical activity and heart rates and questions could be explored such as: What does this mean for a 30 year old, 50 year old and so on? What are the key understandings and how have these formulae come about?

Example 2 – Say No to Pain

In addition to the mathematical literacy items, PISA 2003 incorporated a new element, problem-solving skills, to assess "the ability of students to use cognitive processes to solve real cross-disciplinary problems where the solution path is not obvious" (OECD, 2003, p. 7). This new element was seen as important in reflecting the OECD's aim of describing the skills and abilities that students use in real-world situations and the perceived importance of these skills for participating in modern day society. Once again, the sound principles, underpinning the assessments, do reflect the educational movements of quantitative literacy and reform of school curricula but, do not produce a commensurate shift in the development of the items themselves. The problem-solving items are structured similarly to those included in the International Adult Literacy and Life Skills Survey (ALLS) (www.ets.org/all) where information is

presented by way of a set of instructions, a document, a time-table, or other authentic context and then questions probe the knowledge that students have gained from the item, not their understandings of what this knowledge might mean.

A sample task, entitled "*Say No to Pain*" (p. 161) sets up a brief context of the difficulty in choosing pain killers to suit the appropriate purpose because of the vast number on the market. It then describes, by way of a table, four available brands of pain killer and their associated details regarding dosage, relief symptoms, description, and cautionary notes. The assessment items ask the student to: rank the pain killers from weakest to strongest, identify two that may cause more stomach irritation, interpret dosage information, and choose appropriate pain killers for particular patients, described by age and ailment. As with the mathematical literacy items, the questions are focused on assessing students' ability to glean relevant knowledge from the data, not to explore their understandings of the impact of pain killer choices. What are the implications of taking the wrong dose? What if a child is given an adult dose?

Classroom-based units of work

Out of the curriculum reform movement has come an increasing use of some form of integrated learning in classrooms. It is founded on a belief that promoting the connection of ideas and relevance of these ideas to students has a motivating power that will result in rich learning (Beane, 1991). In the United States thirteen mathematics curriculum projects, funded by the National Science Foundation (NSF), were created to reflect a view of the value of forming broader understandings in the mathematics classrooms and to connect concepts with everyday applications and work in other disciplines (Berlin, 2003). Australian educators have also incorporated an integrated approach in the classroom in response to these issues and in particular, the desire to create meaningful, engaging learning for adolescent students (Budgen, Wallace, Rennie, & Malone, 2003).

There are many examples of units of work where mathematics has been approached from a real-world setting or from another discipline, such as science or literature (Billings & Lakatos, 2003; Leonard & Campbell, 2004; O'Donnell, 2001; Ronau & Karp, 2001). Two examples are discussed here to illustrate this approach. It is noted that these examples do not reflect a true transdisciplinary framework as has been developed with the Essential Learnings in Tasmania. They do, however, illustrate a reform view of the importance of mathematics in context, which is one important element of quantitative literacy.

Example 1 – Power over Trash

Research (Ronau & Karp, 2001) conducted in a sixth grade class over a week examined the influence of integrating mathematics and science concepts around a children's story, "The Wartville Wizard". The story was about a man who takes on the world of litter and it was used as a meaningful introduction to the problem of garbage. The class then proceeded on a "data-supported campaign against litter" (p. 27). Tasks included gathering litter from the school grounds, organising it, and assessing their collections. Broader issues of safety and sanitisation were also discussed. Graphing skills were developed by representing the data in a variety of ways: strip graphs, circle graphs, bar graphs, pie charts, and using graphing calculators. Connections were made with real-world data, and environmental and

recycling issues were explored. The researchers concluded that the students "better understood the problem of litter through collecting and analysing actual data" (p. 31)

Although this example demonstrates an authentic learning experience that reflects a reform-based view and acknowledges the importance of developing the students' understandings, the conclusion that students "better understood" is not supported by any discussion of the form of assessment upon which this conclusion was based. The unit would situate well in the Essential Learning key element 'creating sustainable futures'(see Figure 1). Assessment needs to move to a model that will enable educators to assess not only the quantitative learning but also the understandings relevant to this particular unit of work.

Example 2 – Using the stockmarket for relevance in teaching number sense
A research project (Leonard & Campbell, 2004) was developed from a foundational goal of involving students in learning mathematics in non-traditional ways. A thematic unit of work was piloted with sixth-grade students where the real-world context of the stock market formed the basis for learning fractions, decimals, and place value. The teacher wanted the students to understand the fluctuating nature of the stock market and the risks involved in buying stocks. The virtual scenario presented to the students was based upon inheriting $10,000 from an aunt and making investment decisions with the aim of saving for their future college education. Students followed the stocks chosen over a period of six weeks and kept records of the movement in the value of these stocks. They developed their number sense skills during the course of the unit. They undertook authentic experiences such as writing to local brokerage firms to request a prospectus of the stock they had chosen and kept a portfolio of their work. The research concluded that "exposure to such content empowers students with the knowledge needed to make sound financial decisions in the future" (p. 299).

The assessment of the understanding goals, with respect to both number sense and financial decision-making, is not discussed in the article although it is likely that evaluations were made based upon the student portfolios. Educators interested in the bringing together of disciplines for the purpose of teaching concepts in a contextual framework are grappling with this issue. "How will mathematical and scientific understanding be assessed, particularly when the concepts may be embedded in rich and complicated contexts?" (Frykholm, 2002).

Conclusion

Quantitative literacy, by its very definition, embodies understanding and is developed by the application of skills and concepts in real-world settings. Wiggins (2003) discusses the need for evidence of students' abilities to use mathematics in varying and complicated situations. "Without anchoring mathematics on a foundation of fascinating issues and 'big ideas' there is no intellectual rationale or clear goal for the student" (p. 124). "We want to regularly assess student work with numbers and numerical ideas in the field" (p. 125). This paper has considered the need for a broader view that incorporates the concurrent assessment of quantitative literacy with the very 'field' that it is anchored in. By examining the positioning of quantitative literacy in a reform-based curriculum setting, it has become clear that the nature of

assessment is critical. Existing assessment models have yet to address the need for the assessment to incorporate two major elements within a reform-based curriculum framework: the skills and concepts being applied and the contextual frameworks within which they are being applied.

In the specific case of the Essential Learnings Framework, the assessment of quantitative literacy must occur alongside the assessment of the key element(s) in which it is embedded. Such an assessment model is by nature multi-dimensional and would assess student understandings of quantitative literacy alongside their understandings of: maintaining health and well-being, building social capital, being ethical, creating sustainable futures, building and maintaining identity and relationships, creating and pursuing goals, valuing diversity acting democratically, understanding the past and creating preferred futures, investigating the natural and constructed world, and understanding and evaluating technological solutions.

Much research is needed to devise, test and evaluate a new model of the assessment of quantitative literacy in the new reform-based environment. Such a model has the potential to enhance students' quantitative literacy abilities and their conceptual understandings of the connections between knowledge and its real-world application. This paper has sought to begin the debate and consideration of the issues, the resolution of which will contribute to the structuring of such a model.

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